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9

Lubricant Application

After the proper lubricant for an application has been selected, it must be delivered, in the correct quantities and under the specific application conditions, to the elements that require lubrication. Two categories of lubricant application are prevalent: *all-loss* methods, where a relatively small amount of lubricant is applied periodically and after use leaks or drains away to waste; and *reuse* methods, where the lubricant leaving the elements is collected and recirculated to lubricate again. Application methods such as some pedestal bearings and enclosed splash-lubricated gear cases are considered to be forms of reuse. Various centralized application systems, such as centralized grease systems and mist systems (not to be confused with circulation systems), are actually specialized all-loss systems and are discussed separately. Reuse application systems are preferred because they conserve lubricant, minimize waste, and help control environmental pollution. They also provide other advantages, as discussed in this chapter.

I. ALL-LOSS METHODS

Most open gears and wire ropes, many drive chains and rolling element bearings, and some cylinders, bearings, and enclosed gears are lubricated by all-loss methods. Nearly all grease lubrication (except sealed, packed rolling element bearings) represents the all-loss approach. Only relatively small amounts of grease are applied, mainly to replenish the lubricating films, but in some cases to flush away some or all of the old lubricant and contaminants.

A. Oiling Devices

The oldest known method of applying lubricants is by using an oil can. With high viscosity lubricants such as are used on open gears and some wire ropes, a paddle, swab, brush, or caulking gun may be required instead, all these are variations of hand oiling.

While still widely used, hand oiling has several disadvantages. Immediately after

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application there is usually an oversupply of oil, and excessive leakage or throwoff occurs. Then follows a period when more or less of the proper quantity of oil is present; and finally, depending on the frequency of application, there is usually a period when too little oil is present (starvation). During this latter period, wear and friction may be high. Also, with hand application, lubrication points may be neglected, either because they get overlooked or because they are difficult or hazardous to reach. Oil leakage onto machine parts, floors, or goods being processed can be hazardous and costly in terms of safety and/or materials wasted. Hand oiling is costly both in terms of labor and because of lost production if machines must be shut down for the purpose. Many devices have been developed and are in wide use to overcome some of the disadvantages of hand oiling. The objective of these devices is to feed oil continuously or at regular, frequent intervals in small amounts with as little attention as possible.

1. Drop Feed and Wick Feed Cups

Drop feed and wick feed cups, shown in Figures 9.1 and 9.2, are often used to supply the small amount of oil required by high speed rolling element bearings, thin film plain bearings and slides, and some open gears. The rate of oil feed from the drop feed cup can be adjusted with a needle valve, while the wick feed can be adjusted by changing the number of strands in the wick. Both devices have the disadvantage of requiring to be started and stopped by hand when the machine is started or stopped.

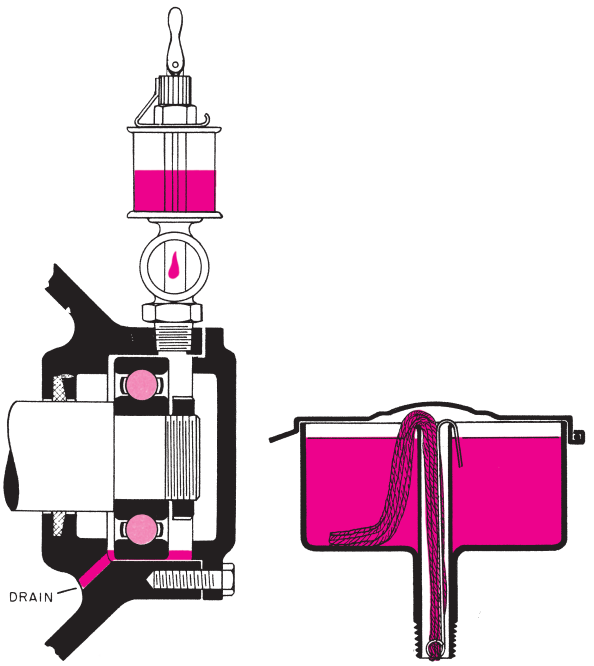

Figure 9.1 Drop feed (left) and wick feed (right) cups. In the drop feed application, the oil drops fall on the lock nut, which throws a spray of oil into the bearing.

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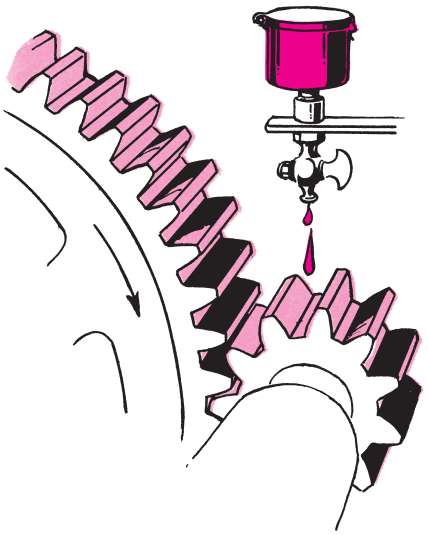

Figure 9.2 Drip oiling system.

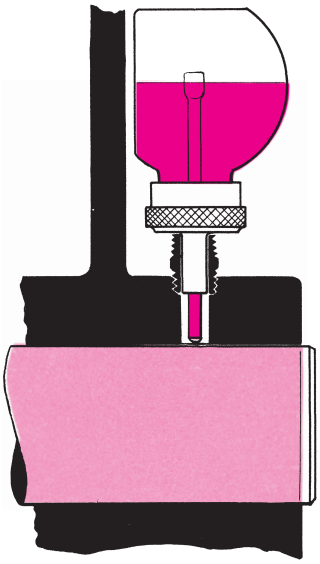

Figure 9.3 Bottle oiler.

Some drop feed cups are controlled by solenoid-operated valves, which eliminate the problems of manual actuation.

2. Bottle Oilers

In a typical bottle oiler (Figure 9.3), the spindle of the oiler rests on the journal and is vibrated slightly as the journal rotates. This motion results in a pumping action, which forces air into the bottle, causing minute amounts of oil to feed downward along the spindle to the bearing. The oil feed is more or less continuous but stops and starts when the machine is stopped or started.

3. Wick and Pad Oilers

In one type of wick oiler (Figure 9.4), a felt wick is held against the journal by a spring. The wick draws oil up from the reservoir by capillary action, and the turning journal wipes oil from the wick. No or little oil is fed when the journal is not turning. In another variation (Figure 9.5), the wick carries oil up to the slinger, which throws it into the bearing in the form of a fine spray. In both cases, oil leaking out along the shaft drains back to the reservoir, so the devices have some elements of a reuse system.

Pad oilers are sometimes used for long, open bearings. One end of the pad rests in an oil reservoir, while the other end rests along the journal. Capillary action draws oil up the pad, where it is wiped off by the turning journal.

4. Mechanical Force-Feed Lubricators

Force-feed lubricators are used in applications requiring positive feed of lubricants under pressure. A variety of force-feed lubricators are in use. In the type shown in Figure 9.6, oil is drawn from the reservoir in the base on the downstroke of the single plunger pump

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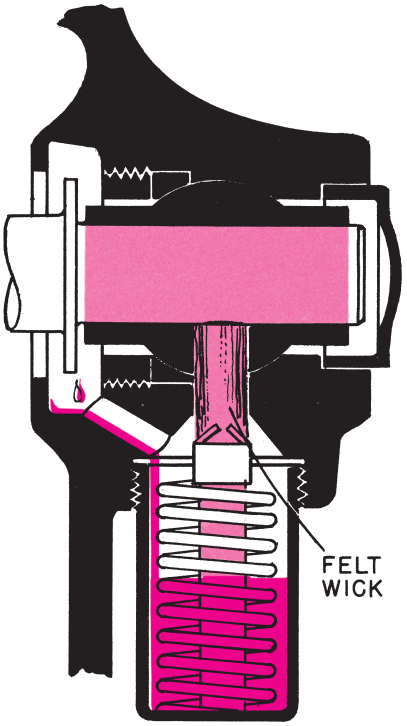

Figure 9.4 One type of wick oiler.

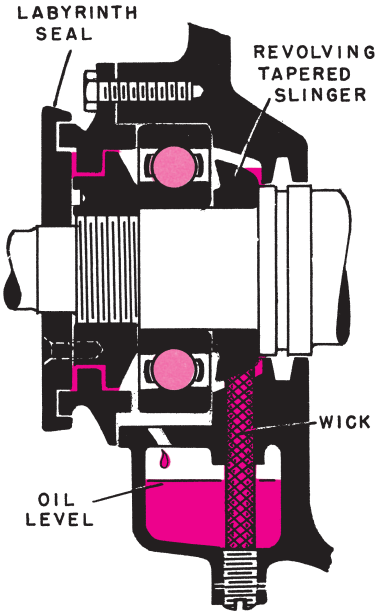

Figure 9.5 Wick-fed spray oiler.

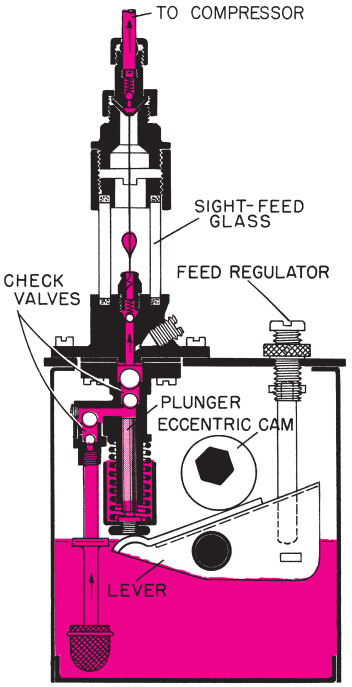

Figure 9.6 Force-feed lubricator with liquid-filled sight glass.

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and forced under pressure on the upstroke, through the liquid-filled sight glass to the delivery line. The pump is operated by an eccentric cam and lever, which can be driven from a shaft on the machine or operated by a hand crank. The stroke of the pump can be regulated to adjust the oil feed rate, which can be estimated by counting the drops as they pass through the liquid-filled sight glass.

Some modern additive oils can cloud the liquid in the sight glasses of this type of lubricator, so lubricators with dry sight glasses are sometimes used. One of these is shown in Figure 9.7. The pump shaft is cam shaped in cross section and causes the plunger to move up and down. Specially shaped surfaces (*A*) at right angles to the pump shaft axis also act on the eccentric head of the plunger, causing it to oscillate about its axis. On the upstroke of the plunger, the head is turned so that the suction slot registers with the suction channel port, while the delivery slot, which is 90° away, is blanked off. Oil is drawn up the suction tube and over to the sight glass, where the falling drops may be observed. From the sight glass, the oil flows to the space below the plunger. On the downstroke of the plunger, the head rotates to align the delivery slot with the delivery channel port; the suction slot is blanked off. As the plunger is pushed downward, it forces oil out through the delivery tube. The plunger stroke, and amount of oil pumped, can be adjusted by means of the lift-adjusting screw. The lubricator can be driven by the machine or turned by a hand crank.

Mechanical force-feed lubricators are used on large stationary and marine diesel engines, cylinders of reciprocating steam engines, gas engines, and reciprocating compressors to supply lubricant to the cylinders. One pumping unit is used for each cylinder feed, and all the pumping units are usually mounted on a single reservoir.

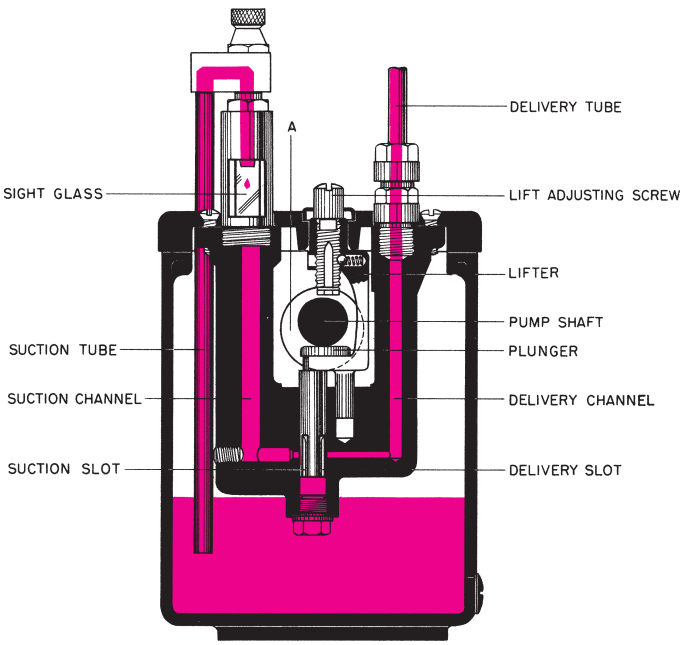

Figure 9.7 Force-feed lubricator with air drop sight glass.

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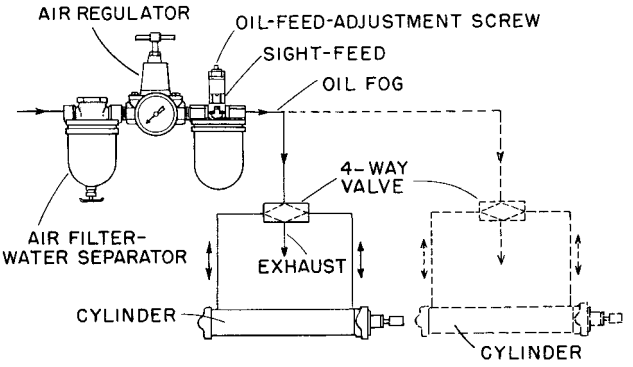

Figure 9.8 Fog lubricator for pneumatic cylinders.

5. Air Line Oilers*

Air-powered cylinders and tools are often lubricated by ''lubricating'' the compressed air supply. Pneumatic cylinders used for actuating parts of machines may be lubricated by means of an oil fog lubricator such as that in Figure 9.8. The flow of air through the lubricator creates an air–oil fog that carries sufficient oil to lubricate the cylinders.

Air tools such as rock drills and paving breakers are often lubricated by means of air line oilers. The air line oiler consists of an oil reservoir that contains a device for feeding a metered amount of atomized oil into the airstream. It is coupled into the air hose a short distance from the drill, and a fine spray of oil is carried from it to lubricate the drill wearing surfaces that are reached by the air. A method of varying the rate of oil feed is provided so that the oil feed can be adjusted to the drill and drilling conditions.

In the air line oiler (Figure 9.9), air for rock drill actuation passes through the center tube, and line pressure is applied to the oil reservoir via port *A* and the vertical drilled passages shown on the left. As the result of a venturi effect, a reduced pressure prevails at port *B*. Because of the difference in pressure, oil feeds through the valve (right view) and port *B* into the air stream.

6. Air Spray Application

Some open gear and wire rope lubricants, including some grease-type materials, are applied by means of hand-operated air spray equipment that uses either external mixing nozzles or airless atomizing equipment. This approach, however, has the same disadvantages as hand oiling. A number of automatic or semiautomatic units such as that shown in Figure 9.10 have been developed to overcome some of these problems.

B. Grease Application

Greases are used mainly for rolling element bearings, flexible couplings, and thin film plain bearings and slides. Greases are also used in some open and enclosed gear applica-

* Air line oilers and air spray lubrication (Section 1.A.6) comprise a specialized variation of oil mist lubrication, which is discussed at the end of this chapter.

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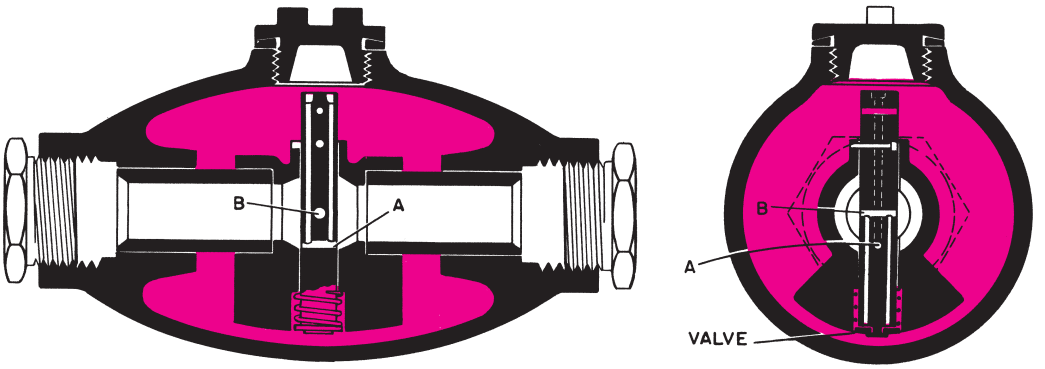

Figure 9.9 Air line oiler. Oil is drawn into the airstream through the port *B* by venturi effect. The enlarged section around the valve acts as a pendulum to swing the valve and keep the oil intake submerged in oil regardless of the position of the outer housing.

tions. Because of the lower leakage tendencies of greases, periodic application with a hand or air-powered grease gun overcomes many of the disadvantages of hand oiling; but, as with any manual lubrication method, fittings will be overlooked and the cost of application is usually high. Therefore, central grease lubrication systems are being used more frequently, and a number of bearings are being ''packed for life.''

Many rolling element bearings are manually packed at the time they are installed, and periodically thereafter, as is the case with automotive wheel bearings. Grease is forced

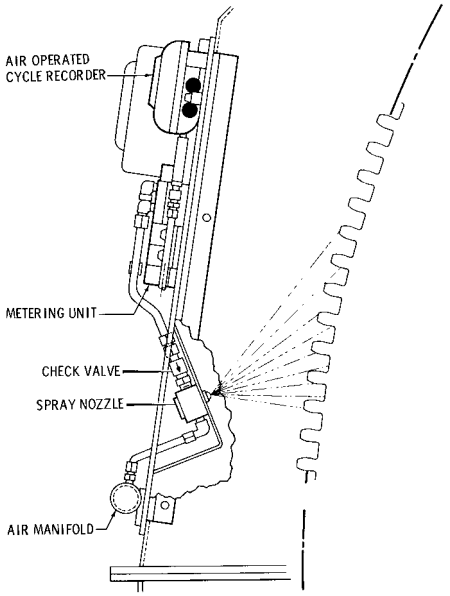

Figure 9.10 Spray panel for open gear lubrication.

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into the spaces between the rolling elements by hand or with a bearing packer, and a moderate amount of grease is placed in the hub. The housing must not be filled completely, for there would be no place for the grease between the raceways to go when the bearing was operated. Excessive churning of the grease and overheating would then result.

Bearings intended for power grease gun lubrication must have provision for pressure relief to prevent pressure buildup and permit purging of old grease. This is sometimes accomplished by allowing sufficient clearance in the seals, but the same effect can also be achieved with a relief valve or a drain plug such as that in Figure 9.11. When a bearing of the latter type is relubricated, the drain plug should be removed and left out until the bearing has been operated long enough to expel all excess grease.

A wide range of self-contained grease lubrication devices ranging from spring-loaded reservoirs that feed small amounts continuously to battery- or gas-operated units that can be programmed to activate at specified intervals. Figure 9.12 shows an electromechanical lubricator that contains a motor, a piston pump, a gearbox, and a microprocessor capable of delivering precise lubricant quantities at specified intervals. These units are available in a range of sizes capable of single- or multiple-point distribution.

''Packed for life'' bearings are used for many light- to medium-duty services. These bearings have seals and are packed at the factory with a special long life grease intended to last for the life of correctly applied bearings. In some cases, the service range of bearings of this type is extended by making provision for relubrication by one of the following methods: removing one seal and applying grease through the seal by means of a gun with a hollow needle, or forcing grease through holes in the outer ring. Care is necessary with the latter method because only a small amount of pressure will dislodge some seals.

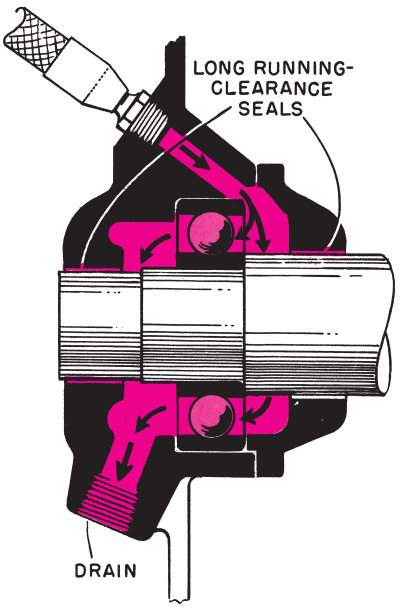

Figure 9.11 Free purging housing design, which permits good purging of old grease from both sides of the bearing when new grease is applied.

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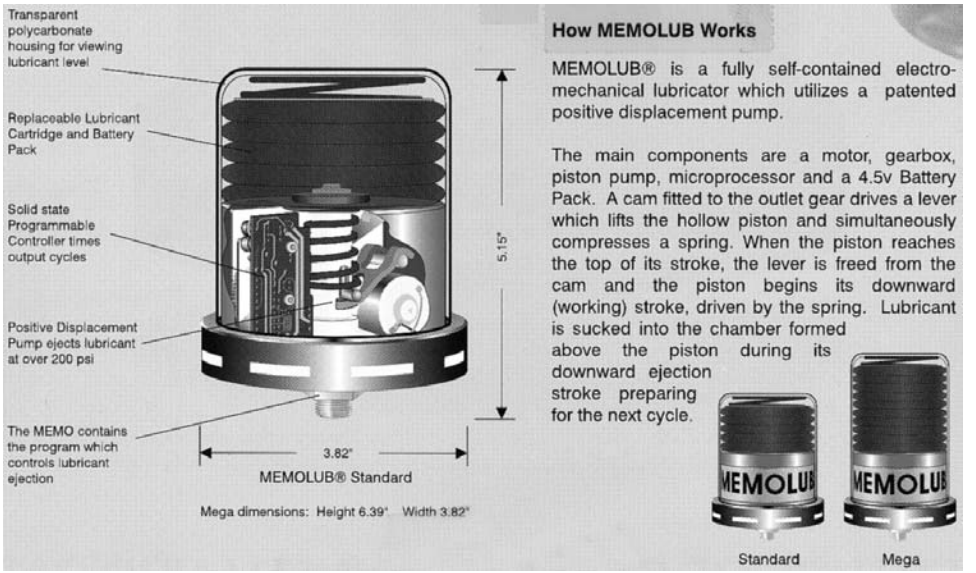
Transparent polycarbonate housing for viewing lubricant level
Replaceable Lubricant Cartridge and Battery Pack
Solid state Programmable Controller times output cycles
Positive Displacement Pump ejects lubricant at over 200 psi
The MEMO contains the program which controls lubricant ejection
5.15"
3.82"
MEMOLUB® Standard
Mega dimensions: Height 6.39" Width 3.82"
How MEMOLUB Works
MEMOLUB® is a fully self-contained electro-mechanical lubricator which utilizes a patented positive displacement pump.
The main components are a motor, gearbox, piston pump, microprocessor and a 4.5v Battery Pack. A cam fitted to the outlet gear drives a lever which lifts the hollow piston and simultaneously compresses a spring. When the piston reaches the top of its stroke, the lever is freed from the cam and the piston begins its downward (working) stroke, driven by the spring. Lubricant is sucked into the chamber formed above the piston during its downward ejection stroke preparing for the next cycle.
MEMOLUB
MEMOLUB
Standard
Mega

Figure 9.12 Electromechanical lubricator.

II. REUSE METHODS

Reuse methods of oil application include circulation systems supplying lubricant for one or more machines and self-contained systems such as bath, splash, flood, and ring oiling.

A. Circulation Systems

The term ''circulation system'' generally refers to a system in which oil is delivered from a central reservoir to all bearings, gears, and other elements requiring lubrication. All the oil, disregarding minor leakage, drains back to a central sump and is reused. Two principal variations of this type of system are used—namely, pressure feed and gravity feed. In pressure feed systems, a separate sump and reservoir may be used, or the two may be combined (Figure 9.13). The oil is pumped directly to the parts requiring lubrication. Where a separate sump is used, it may be either ''wet'' (drain is located so that a certain amount of oil remains in the sump at all times) or ''dry,'' (drain is located and sized so that the sump remains essentially empty at all times). In gravity feed systems, oil is pumped to an overhead tank and then flows under gravity head to the elements requiring lubrication.

In either type of system, very often the rate of flow is determined primarily by what is needed for cooling. This amount of oil usually will be more than is needed for lubrication. Means of cooling and purifying the returned oil are often included in circulation systems.

Although the many types of application for circulation systems require considerable variations in size, arrangement, and complexity, in a general way, circulation systems can be considered in one of three groups:

1. Systems comprising a compact arrangement of pump, reservoir, and oil passages built into the housing of the lubricated parts such as that in Figure 9.13

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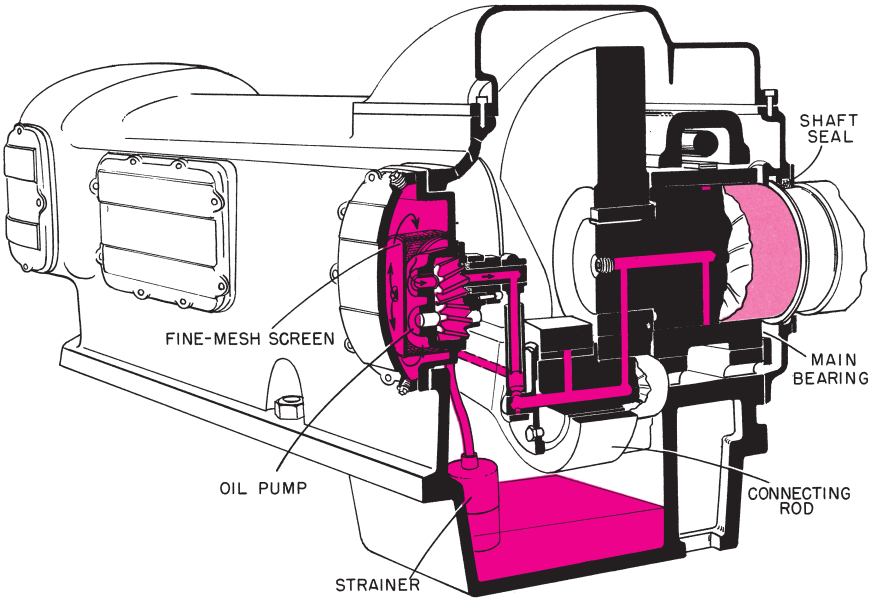

Figure 9.13 Pressure-feed circulation system for horizontal, duplex two-stage compressor: cutaway view through the main and crankpin bearings of the right-hand frame. The spiral gear oil pump draws oil from the reservoir through a strainer and forces it through a fine mesh screen and the hollow pump arm to the crankpin bearing. Excess oil is bypassed to the reservoir through a relief valve (not shown). From the crankpin bearing, oil flows under pressure through internal passages to the main bearing, to the crosshead pin bearing and crosshead guides.

2. Systems employing a multicompartment tank combining reservoir and purification facilities (Figure 9.14)
3. Systems comprising an assembly of individual units (reservoir, oil cooler, oil heater, oil pumps, purification equipment, etc.)

The system illustrated in Figure 9.15 is fairly typical of the third type. Returning oil drains to a settling compartment, entering the reservoir at or just above the oil level. Water and heavy contaminants settle, and the sloping bottom of the reservoir helps to concentrate these impurities at a low point from which they can be drained. Partially purified oil overflows a baffle to the clean oil compartment. In some systems, especially where large reservoirs are used, baffles may be omitted. The clean oil pump takes oil, usually through a suction strainer, and pumps it to a cooler, optional oil filter, and then to bearings, gears, and other lubricated parts. The pressure desired in the oil supply piping is maintained by means of a relief valve, which discharges to the reservoir at a point below the oil level. A continuous bypass purification system is shown. The pump takes 5–15% of the oil in circulation from a point above the maximum level of separated water in the reservoir and pumps it through a suitable filter back to the clean oil compartment. The following discussion of good practices in circulation system design refers primarily to systems of this type, but the ideas presented are fundamental to most systems.

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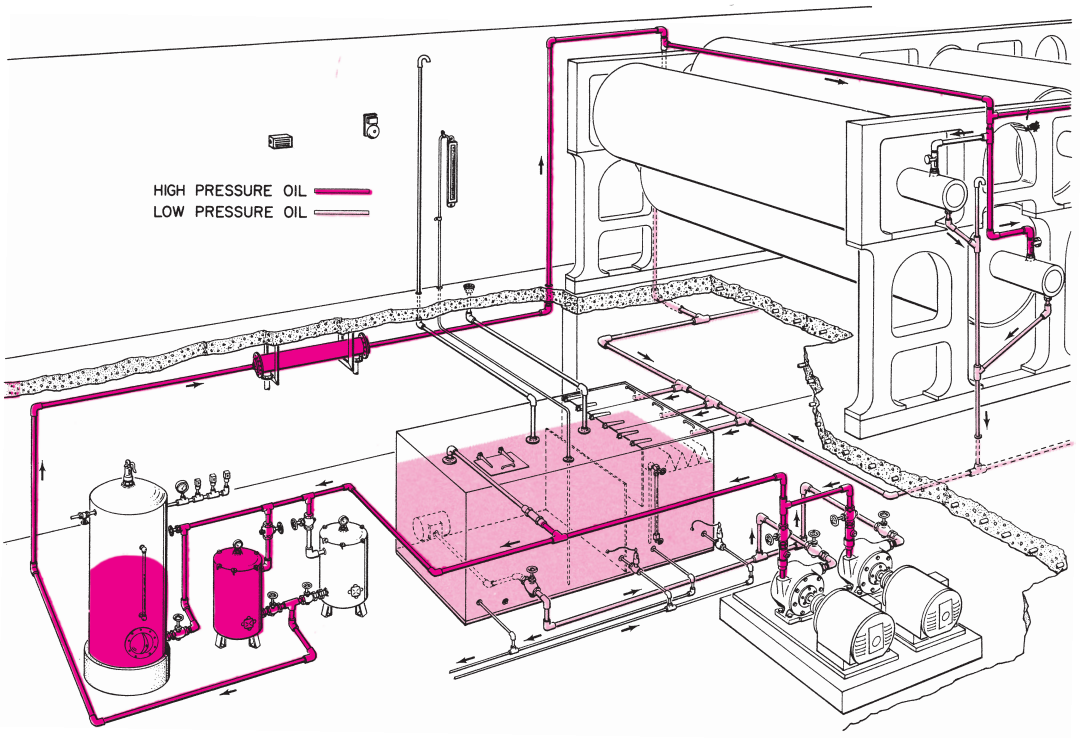

Figure 9.14 Paper mill dryer circulation system.

1. Oil Reservoirs

The bottom of an oil reservoir should slope at a ratio of more than 1 to 25 (4%) toward a drain connection, which should be located at the lowest point in the reservoir. This construction promotes the concentration of water and settled impurities and permits their removal without excessive loss of oil. In addition, it permits more complete removal of flushing oil or solvents used in cleaning operations prior to start-up or during an oil change. Where oil is taken directly from the reservoir for purification, it should be removed close to the low point but above any water or settled impurities. An opening or openings above the oil level, adequate for inspection and cleaning, should be provided. Large reservoirs should have an opening large enough for a person to enter. These and any other openings should have well-secured, dust-tight covers. Before personnel enter enclosed reservoirs, all safety precautions should be taken.

A connection should be provided at the highest point in the reservoir for ventilation. Proper ventilation results in the removal of moisture-laden air and thereby reduces condensation on cooler surfaces above the oil level and subsequent rusting of these surfaces. Ventilation fixtures should be designed with air filters or desiccant breathers to prevent entrance of airborne contaminants and excessive moisture. Instead of natural ventilation, where a source of water contamination is common—for example, large steam turbine systems or paper mill dryer systems—medium-sized and large reservoirs should be pro-

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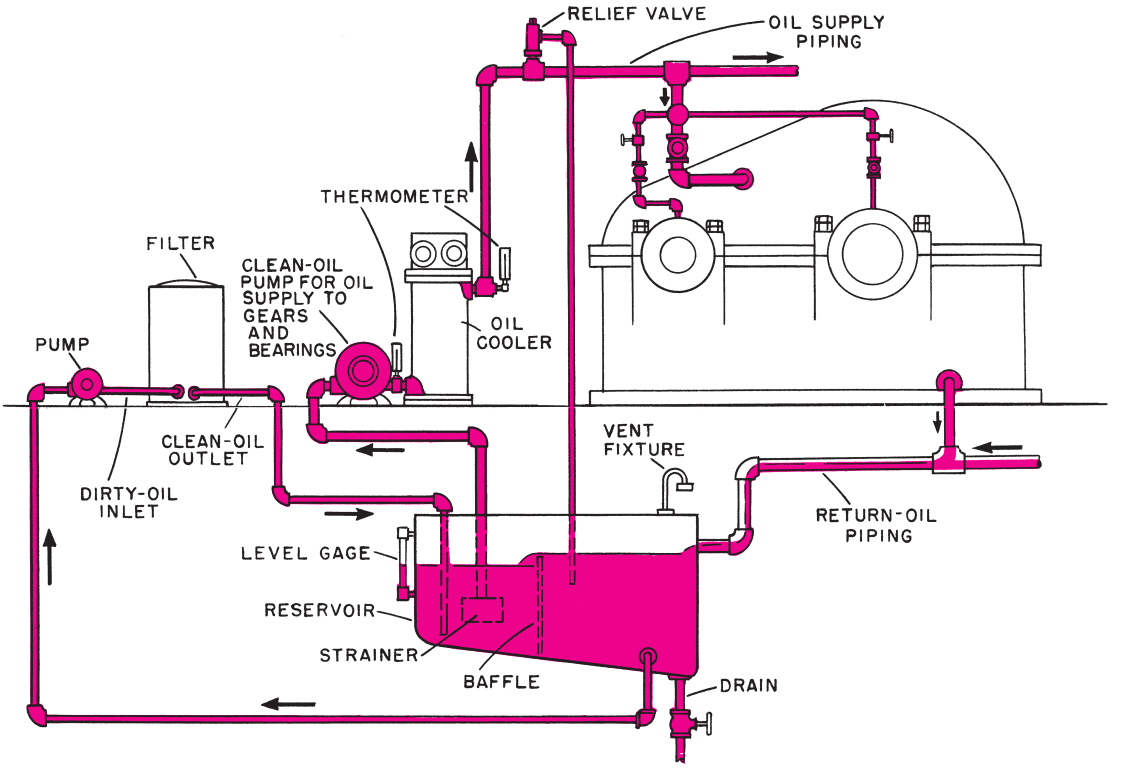

Figure 9.15 Circulation system diagram: elements illustrated include one type of pressure circulation system and several commonly accepted practices.

vided with a ''vapor extractor,'' capable of maintaining a slight vacuum in the air space above the oil level. Too high a vacuum should be avoided, however, since it might pull plant atmospheric contaminants into the lubrication system.

The main oil return connection should be located at or slightly above the oil level and remote from the oil pump suction. Returning oil should not be permitted to drop from a considerable height directly into the oil body, since this action tends to whip air into the oil and cause foaming or to hold water and contaminants in suspension. Instead, the fall of oil should be broken and dispersed by means of a baffle, sheet metal apron, or fine screen. A line that may carry any air should never discharge below the oil level. A connection for the return to the reservoir of a ''solid'' stream of oil, as from a pressure relief valve, should be placed about 6 in. (150 mm) below the oil level.

It is convenient to consider reservoir size in terms of the oil volume flowing in the system. The reservoir should be large enough to ensure that oil velocity in it will be low and that the oil will have sufficient rest time to allow adequate separation of water and entrained solids, separation of entrained air, and collapse of any foam that may exist. In practice, reservoir sizes range from a suggested minimum of 2 times system flow per minute to over 40 times. Many representative systems have reservoirs of 5–10 times system flow per minute. Newer design large steam turbine systems and large paper mill dryer systems will typically be in the range of 40 plus times total pumping capacity.

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2. Pump Suction

The clean-oil pump suction opening should be above the bottom of the reservoir to avoid picking up and recirculating settled impurities. However, it must be below the lowest oil level that may occur during operation. Where there is considerable variation of the oil level in the reservoir and it is desired to take oil at or near the surface, a floating suction may be used. Floating suction is frequently used in reservoirs of systems exhibiting constant, extreme water contamination. The oil supplied to the circulation systems from the top of the reservoir will have the least water contamination.

3. Bearing Housings

The floors of bearing housings should have a slope of about 1 in 50 (2%) toward the drain connection. The design should be such that there are no pockets to trap oil and prevent complete drainage. Shaft seals should be adequate to prevent loss of oil or the entrance of liquid or solid contaminants. Any type of breather or vent fixture on a bearing housing should be provided with an air filter to keep out dust and dirt.

4. Return Oil Piping

Gravity return oil piping should be sized to operated about half-full under normal conditions, and it should have a slope of at least 1 in 60 (1.7%) toward the reservoir. Any unavoidable low spots should have provision for periodic water removal. Severe piping bends, such as 90° or more out of the bearing housings, should be avoided to minimize the potential for oil backing up into the bearings causing overheating and increased oil leakage. Smooth flow passage of return oil is also important in avoiding buildup of deposits in return piping.

5. Circulation System Metals

Exclusive of bearings, the parts of a circulation system should preferably be made of cast iron or carbon steel. Fittings of bronze are acceptable. Stainless steel tubing is very good. Aluminum alloy tubing is acceptable as far as chemical inertness with oil is concerned, but it may not have sufficient structural strength for high pressure lines. No parts should be galvanized. As a general rule, no parts, exclusive of bearings, should be made of zinc, copper, lead, or other materials that may promote oil oxidation and deterioration. Copper tubing may be used for oil lines in some installations, but should not be used in systems such as those for steam turbines, where extremely long oil life is desired. The use of copper should be confined to those applications for which the oil is formulated specifically to inhibit the catalytic effects of copper.

6. Oil Filtration

Much of the older equipment was equipped with coarse filtration (40 μm or larger) or in some cases, no filtration at all. As machinery became more complex, the importance of oil filtration in helping provide long equipment life was well recognized. This is particularly true in close-tolerance equipment such as servovalves in the machine tool industry or other precise control mechanisms such as governor controls in large turbines. Figure 9.15 showed filtration in a bypass loop, but more commonly this function is found in the pressure side of the supply line to equipment components. In addition to bypass (or kidney loop) filtration and high pressure side filtration, filtration can be in low pressure return

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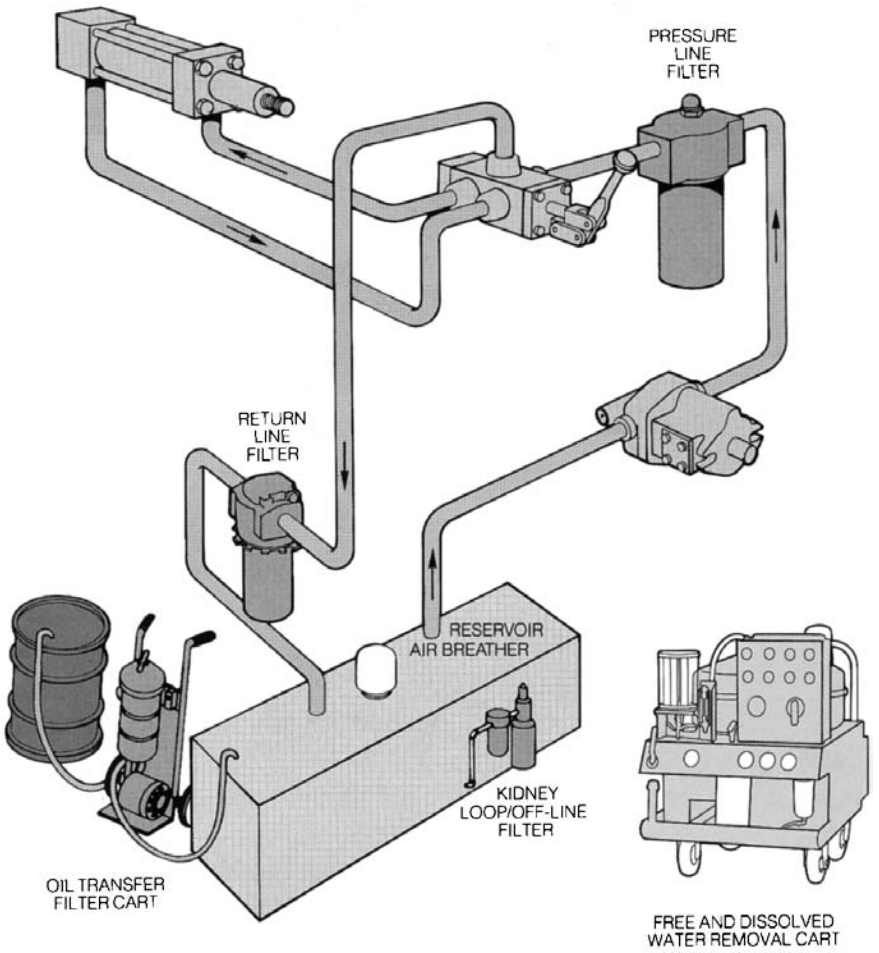

Figure 9.16 Oil filtration and purification.

lines (except not generally used in gravity return systems). Figure 9.16 shows these three main types of filtration and two alternative methods for keeping system oils clean: oil transfer equipment and a freestanding reclamation unit.

7. Oil Coolers

Oil coolers should be located so that all connections and flanged covers are accessible and the tube bundles can be removed conveniently for cleaning. Cooler capacity should be adequate to prevent oil temperature from rising above a safe maximum during the hottest conditions. Means should be provided to control oil temperature at all times by regulating the flow of cooling medium. Where practical, the oil pressure should always be higher than the water pressure to prevent water entering the lubricant in the event of a cooler leak.

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8. Oil Heating

Heating of the oil is desirable or required in circulation system-perhaps the oil is too cold, at start-up condition, to provide adequate flow or lubrication to critical components, or perhaps certain thermal conditions need to be maintained within the system.

The two most common methods of heating oils in industrial applications are steam and electricity. Steam is readily available in many large plants such as fossil fuel fired power plants or paper mills and, most often, steam is used for oil heating requirements. When steam is used, caution should be taken to prevent the exposure of stagnant oil to the full temperatures of the steam. Even saturated condensate steam at 15 psi has a temperature of 335°F. Superheating of these steams can raise temperatures considerably. It is a good practice to maintain heating element surface temperatures below 200°F unless higher quality oils are used and/or oil flow across the heating elements can be maintained.

Oil degradation caused by contact with high heater skin temperatures can take various forms, including the following:

Additive depletion
Additive decomposition
Oxidation
Hydrocarbon cracking

If electrical immersion heaters are used, maximum safe heater watt densities should be determined. This information is available through oil suppliers and manufacturers of immersion heaters. As a general rule, a safe watt density to keep surface element temperatures in the 200°F range is about 5 W/in.^{2}. In many applications it may be desirable to heat oil quickly, and this will necessitate either multiple heating elements or fewer elements with much higher watt densities (higher heating element surface temperatures). In these instances, it will be necessary to maintain sufficient oil velocity across the heating elements to minimize the time that the thin films of oil are in contact with the high temperature surfaces.

9. Monitoring Parameters

The two most common parameters to measure on circulating oil systems are oil temperature and oil level. Oil temperatures should be measured in the oil reservoir, in the supply to components, and on the discharge side of main system operating components, as well as at the inlet and outlet of heat exchangers. Changes in ''normal'' operating temperatures, which may signal a malfunction in the system, could be used to predict a pending component failure.

Maintaining oil at the proper level in the reservoir is important in several respects. It allow adequate retention time in the reservoir to drop out contaminants such as water and abrasive materials, and to dissipate air, while providing some radiant cooling of the system return oil. Maintaining proper levels and temperatures will go a long way to improving oil life, reducing filter costs, and protecting equipment components.

The more sophisticated systems will monitor many more parameters such as pressures, follows, and differential pressures across filters and heat exchangers. Alarms may be used to indicate low levels, high temperatures, low flows, or low pressure. These alarms can be audible (bells) or visual (warning lights) and can be tied into computer systems to monitor operations or to alert personnel remote from the equipment location.

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III. OTHER REUSE METHODS

In addition to circulation systems, a number of other methods of oil application involve more or less continuous reuse of the oil. These are differentiated from integral circulation systems primarily in that pumps are not used to lift the oil.

A. Splash Oiling

Splash oiling is encountered mainly in gear sets or in compressor or steam engine crankcases. Gear teeth, or projections on connecting rods, dip into the reservoir and splash oil to the parts to be lubricated or to the casing walls, where pockets and channels are provided to catch the oil and lead it to the bearings (Figure 9.17). In some systems, oil is raised from the reservoir by means of a disk attached to a shaft, removed by a scraper, and led to a pocket from which it is distributed (Figure 9.18). This variation may be called a flood lubrication system. In either case, the oil returns to the reservoir for reuse after it has flowed through the bearings or over the gears. Accurate control of the oil level is necessary to prevent either inadequate lubrication or excessive churning and splashing of oil.

B. Bath Oiling

The bath system is used for the lubrication of vertical shaft hydrodynamic thrust bearings and for some vertical shaft journal bearings. The lubricated surfaces are submerged in a bath of oil, which is maintained at a constant level. When necessary, cooling coils are placed directly in the bath. The bath system for a thrust bearing may be a separate system or may be connect into a circulation system.

C. Ring, Chain, and Collar Oiling

In a ring-oiled bearing, oil is raised from a reservoir by means of a ring that rides on and turns with the journal (Figure 9.19). Some of the oil is removed from the ring at the point

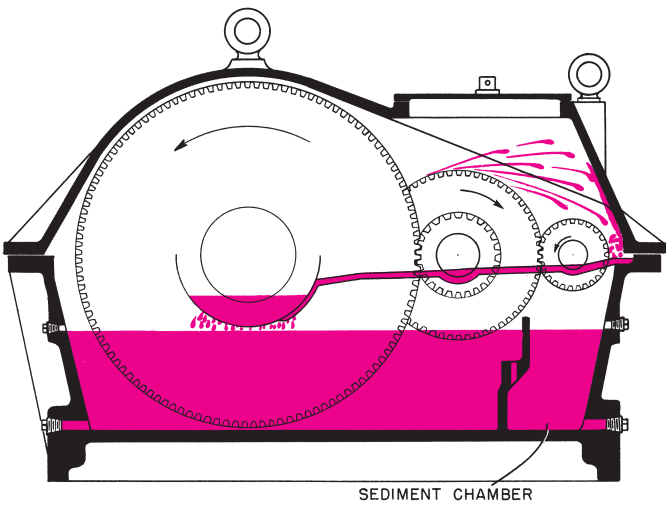

Figure 9.17 Splash oiling system. The gear teeth carry oil directly to some gears and splash it to others and to collecting troughs that lead it to bearings not reached by splash.

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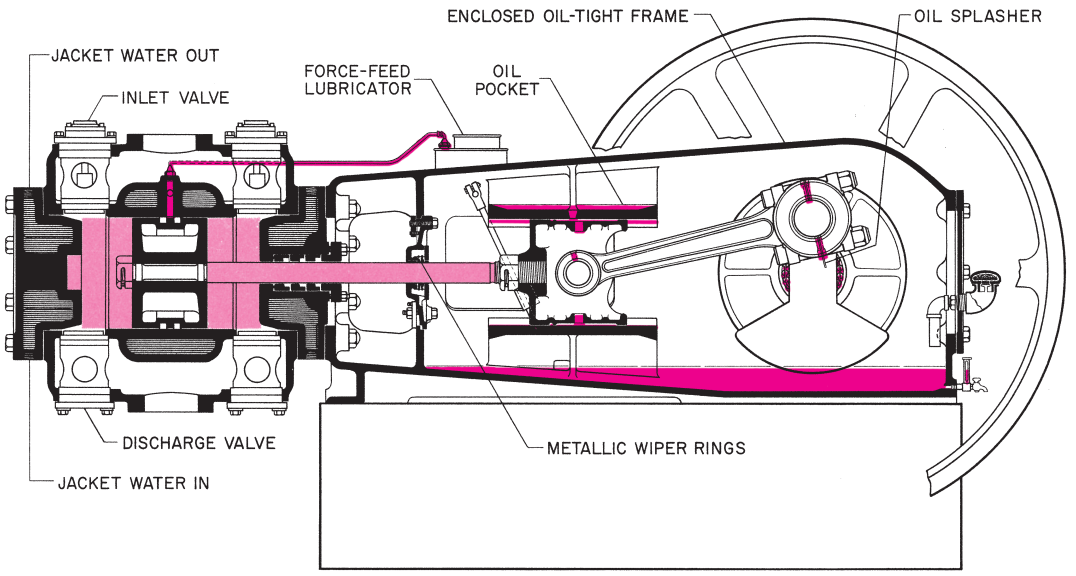

Figure 9.18 Flood lubrication system. In this single-cylinder, water-cooled compressor, running parts are lubricated by the splash and flood method. Crankshaft counterweights and an oil splasher dip into the oil reservoir and throw oil to all bearings. Oil pockets over the crosshead and over each double-row, tapered roller main bearing assure an ample supply for these parts.

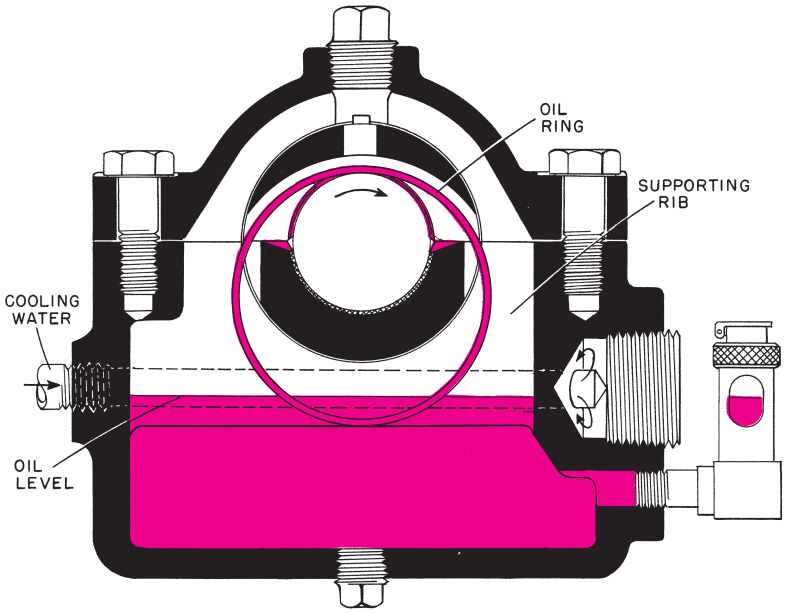

Figure 9.19 Ring-oiled bearing for small mechanical drive steam turbine. The plug in the cap can be removed to observe the turning of the oil ring. The running oil level (indicated) is raised during shutdown as a result of oil draining from the bearing and walls of the housing. The bearing is cooled by means of water passages through supporting ribs on either side of the oil ring slot. The spring cap on the fill and level gage fitting (right) helps keep out dirt.

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of contact with the journal and is distributed by suitable grooves in the bearing. The oil flows through the bearing and drains back to the reservoir for reuse.

Ring oiling is applied to a wide variety of medium speed bearings in stationary service. At high surface speeds, too much slip occurs between ring and journal and not enough oil is delivered. Also, at high speeds, in large, heavily loaded bearings, not enough cooling may be provided.

Oil rings are usually made about 1.5–2 times journal diameter. Bearings more than about 8 in. (200 mm) long, usually required two or more rings. The oil level in reservoirs is usually maintained so that the rings dip less than one-quarter their diameter. The oil level, within a given range, is not usually critical; too low a level may result in inadequate oil supply, however, and too high a level, because of excessive viscous drag, may cause ring slip or stalling. As a result, too little oil may reach the bearing, and ''flats'' may wear on the rings to such an extent that satisfactory performance is no longer possible.

Chains are used sometimes instead of rings in low speed bearings, since they have greater capacity for lifting oil at low speeds.

Where oils of very high viscosity are required for low speed, heavily loaded bearings, a collar that is rigidly attached to the shaft may be used instead of a ring or chain. A scraper is required at the top of the collar to remove the oil and direct it to the distribution grooves in the bearing.

IV. CENTRALIZED APPLICATION SYSTEMS

A number of factors have contributed to the growing use of centralized lubricant application systems. Among these are improved reliability, reduced cost of labor for lubricant application, reduced machine downtime required for lubrication, and, generally, a reduction in the amount of lubricant used through reduction of waste and more efficient use of lubricants.

A. Central Lubrication Systems

A number of types of central lubrication system have been developed. Most can apply either oil or grease, depending on the type of reservoir and pump used. Greases generally require higher pump pressures because greater pressure losses occur in lines, metering valves, and fittings. Pump and reservoir capacities vary depending on the number of application points to be served, ranging from small capacities (Figure 9.20) to units that install on standard drums (Figure 9.21) and systems that operate directly from bulk tanks or bins requiring large volumes of lubricant.

In some systems, called *direct* systems, the pump serves to pressurize the lubricant and also to meter it to the application points. In *indirect* systems, the pump pressurizes the lubricant but valves in the distribution lines meter it to the application points.

Two basic types of indirect systems are in common use, and in turn each type has two variations. In *parallel* systems, also called header or nonprogressive systems, the metering valves or feeders are actuated by bringing the main distribution line up to operating pressure (Figure 9.22, left). All the metering valves operate more or less simultaneously. This type of system has the disadvantage that if one valve fails, no indication of failure is given at the pumping station. However, all the other application points will continue to receive lubricant. In series, or progressive, systems the valves are ''in'' the main distribution line (Figure 9.22, right). When the main distribution line is brought up to pressure, the first valve operates. After it has cycled, flow passes through it to the

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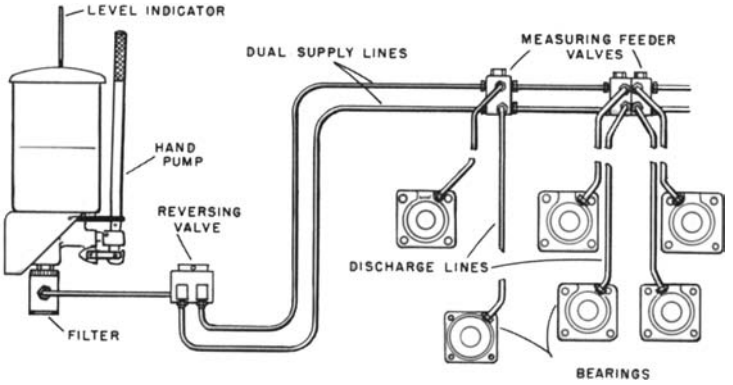

Figure 9.20 Typical hand-operated centralized lubrication system for lubrication of a limited number of points. It can be either a dual-line system (as shown) or a single-line system.

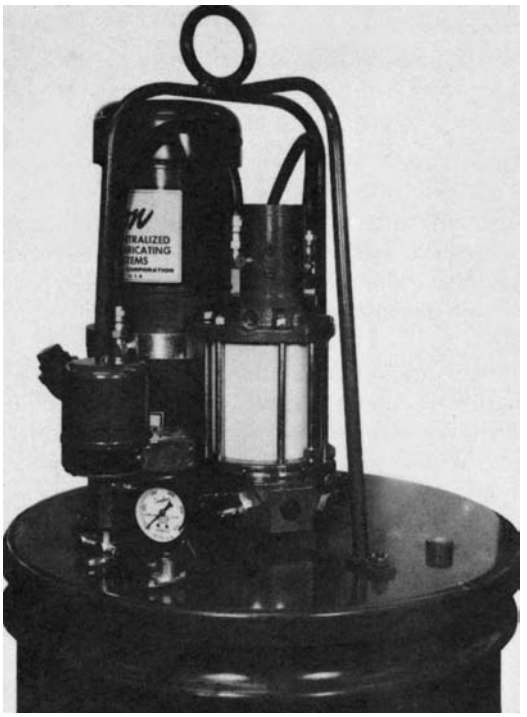

Figure 9.21 Drum-mounted pump and control unit. A standard 400 lb drum serves as the reservoir. The pump can be of one air, electric, or hydraulic type; it develops 3500 psi (24 MPa) pressure. The unit is designed for a single-line, spring return lubrication system.

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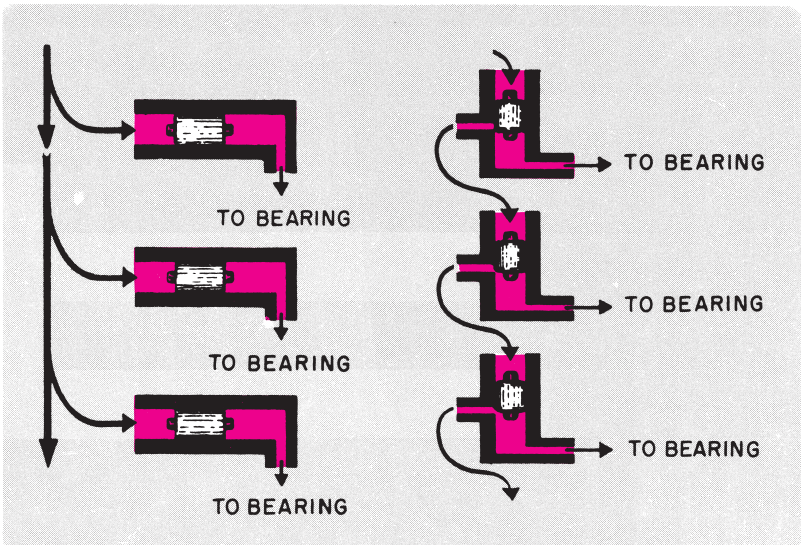

Figure 9.22 Parallel and series lubrication system. In the parallel system (left) the valves are ''off'' the supply line, while in the series system (right) the valves are ''in'' the supply line.

second valve, and then to each succeeding valve in turn. Thus, if one valve fails, all fail, and the pressure rise at the pump or the distribution block can be used to signal that a failure had occurred. The two variations of each of these basic types are as follows.

1. Two-Line System

One variation of the parallel system uses two supply lines (Figure 9.23). The four-way valve directs pressure alternately to the two lines, at the same time relieving pressure in the line that is not receiving flow from the pump. The valve can be operated manually from the machine, cycled by a timer, or controlled by a counter that measures the volume delivered by the pump. The valves are designed to deliver a charge of lubricant to the application point each time the flow in the lines is reversed.

2. Single-Line Spring Return

In the second variation of the parallel system, only a single distribution line is used, the layout is shown in Figure 9.24. As with the four-way valve of the preceding system, the three-way valve may be operated manually from the machine, by a timer, or by a counter measuring pump output. The valves deliver a charge of lubricant when system pressure is applied to them and reset themselves when the system pressure is relieved.

3. Series Manifolded System

In the series manifolded type of system, a single supply line is used. No relief valve is required, since the manifold-type valves automatically reset themselves and continue cycling as long as pressure is applied to them through the supply line. The system can be cycled by starting and stopping the pump.

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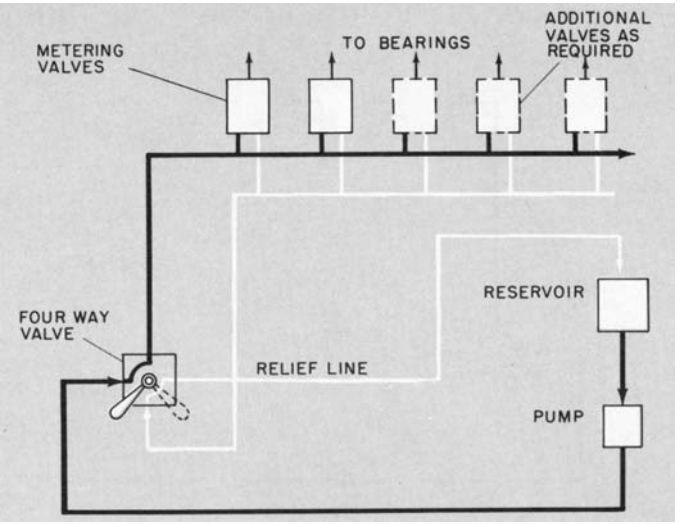

Figure 9.23 Two-line parallel system. The four-way valve, operated manually or automatically, alternately directs pump pressure to one line and then the other. When one line is pressurized, the other line is relieved.

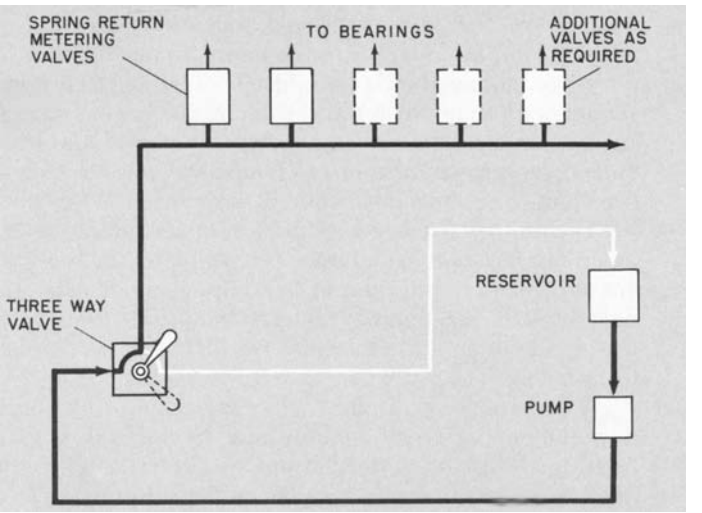

Figure 9.24 Single-line spring return system. The three-way valve, operated manually or automatically, either directs pump pressure into the supply line or relieves the pressure in the line to permit the spring return valves to reset.

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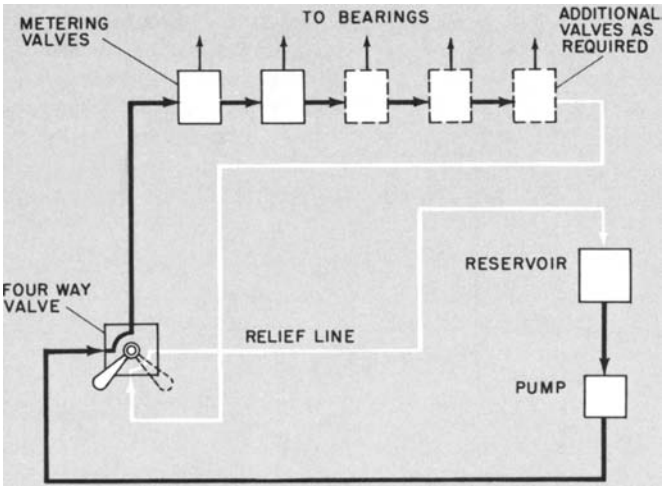

Figure 9.25 Series reversing flow system. The four-way valve, operated manually or automatically, directs pump pressure to one end of the closed-loop supply line while relieving the pressure at the other end.

4. Series System, Reversing Flow

The second series system uses a single supply line with a four-way valve to reverse the flow in it (Figure 9.25). The valves are designed to deliver a charge of lubricant, then permit lubricant flow to pass through to the next valve. When the flow in the supply line is reversed, the valves cycle again in sequence in the reverse order.

B. Mist Oiling Systems

In oil mist lubricators, oil is atomized by low pressure (10–50 psi, 70–350 kPa) compressed air into droplets so small that they float in the air, forming practically dry mist, or fog, that can be transported relatively long distances in small tubing. When the mist reaches the application point, it is condensed, or coalesced, into larger particles that wet the surfaces and provide lubrication. Condensing can be accomplished in several ways. Oil mist systems have proven their reliability in an increasing variety of applications. They are used in all types of industry—from the very light duty service of lubricating dental handpieces to the heavy-duty service of lubricating steel mill backup rolls. In the past, the systems were usually built onto or adapted to existing equipment. Machine tool builders are now designing them into their newer machines, primarily for spindle bearing lubrication, to provide greater reliability and productivity.

An oil mist lubrication system is simply a means of distributing oil of a required viscosity from a central reservoir to various machine elements.

A true oil mist is a dispersion of very small droplets of oil in smoothly flowing air. The size of these droplets averages from 1–3 μm (1 μm = 0.000039 in.) in diameter. In comparison, an ordinary air line lubricator produces an atomized mixture of droplets up to 100 μm in diameter, which are suspended (temporarily in turbulent air flowing at high velocity and pressure). In an air line lubricator system, the air is a working fluid that is

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transmitting power, whereas in an oil mist system, air is used only as a carrier to transport the oil to points where it is required.

The droplet size is a very important consideration in the proper design of an oil mist system. The larger the droplets, the more likely they are to wet out and form an oily film at low impingement velocities. At practical, low flow rates, the size limit is taken to be 3 μm. Droplets over this size will wet or spread out on surfaces quite readily, while particles less than this diameter will not.

A dispersion of droplets less than 3 μm in diameter will form a stable mist and can be distributed for long distances through piping. At the points requiring lubrication, these drops can be made to wet metal surfaces by inducing a state of turbulence, causing small droplets to collide and form into large diameter drops. These larger drops wet metal surfaces to provide the necessary lubricant film.

This formation of larger drop sizes that will wet metal surfaces is referred to as condensation, although other terms (reclassification, condensing, coalescing, etc.) are also used.

Different degrees of condensation may be achieved by using different adapters at the points requiring lubrication. These adapters are usually classified as mist nozzles, spray or partially condensing nozzles, and completely condensing, or reclassifying, nozzles. When high speed rolling element bearings create sufficient turbulence in the bearing housing to cause the droplets to join and wet out, a mist-type nozzle may be used. When gears are being lubricated, it is usually necessary to partially condense the oil mist to ensure that the limited amount of agitation within the gear housing will cause the droplets to coalesce and wet out. When slow moving slides or ways are being lubricated, it is usually necessary to completely condense the oil mist into a liquid which is then applied to the bearing surface.

In a typical oil mist system (Figure 9.26) compressed air enters through a water separator, a fine filter, and an air regulator to the mist generator (a). From the generator the mist is carried to a manifold (b) and then to the various application points (c).

To produce an oil mist, liquid oil is blasted with air to mechanically break it up into tiny particles. Droplets over 3 μm are screened or baffled out of the flow and returned to the sump or reservoir. The resultant dispersion (containing oil droplets averaging 1–3 μm in diameter) is the oil mist to be fed into the distribution system.

The sizes of the venturi throat, oil feed line, and pressure differentials impose physical limits on the viscosity of oil that can be misted. By the judicious use of oil heaters in the reservoir, and in some designs air line heaters to heat incoming air, the viscosity of normally heavy-bodied oils can be lowered to make misting possible. Systems without heaters usually can handle oils up to approximately 800–1000 SUS at 100°F (173–216 cSt at 38°C). If ambient temperatures are much below 70°F (21°C), heat is likely to be needed to reduce the oil's effective viscosity. Also, oils of over 1000 SUS at 100°F (216 cSt at 38°C) usually require heating to lower their effective viscosity and make possible the formation of a stable oil mist.

If the immersion elements in the oil reservoir are not properly adjusted, additional heating of the oil by the heated air will raise the bulk oil temperature until it is able to oxidize quite readily, and varnish or sludge may form in the generator. When heated air is being used, it should be no hotter than necessary to allow easy misting (usually below a maximum temperature of 175°F or 80°C). Also, the oil reservoir immersion elements used in conjunction with heated air should be used primarily at start-up and later, only if necessary to maintain oil temperature during operation. Naturally, the immersion elements

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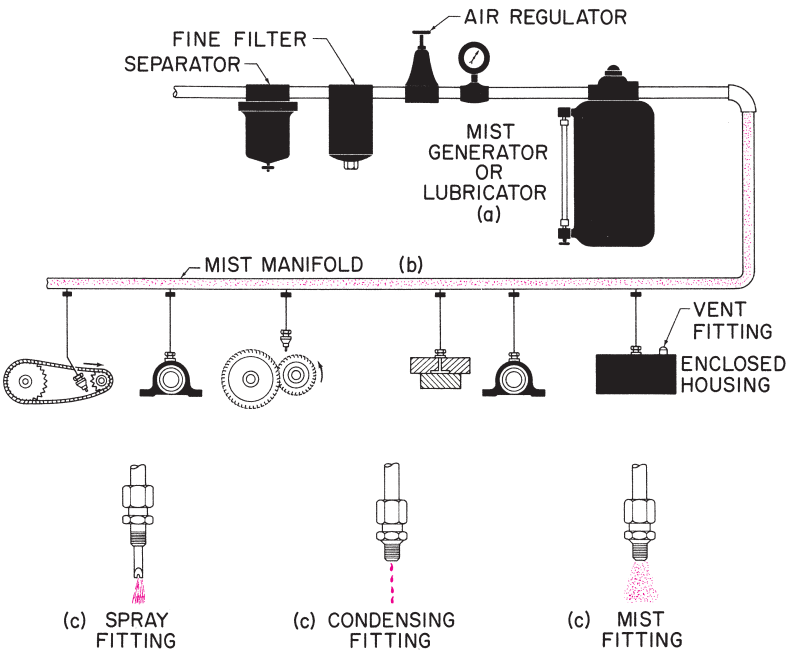

Figure 9.26 Oil mist lubrication system.

should be designed for oil heating and should have a low watt density (e.g., 5 W/in.^{2}, or 0.8 W/cm^2).

In addition to lubrication, mist systems provide other benefits: (1) the flow of air through bearing housings provides some cooling effect, and (2) the outward flow of air under positive pressure helps prevent the entrance of contaminants. Proper venting must be provided to permit this air to flow out of housings.

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